Invigorating Information Technology in Education

Robert Pogson

2008-10-14

Abstract

Information technology has its place in education. We can use it almost everywhere that information must be created, stored, found, retrieved, changed, or presented locally or on the network. It makes sense to use it wherever the raw power of the technology is fastest or does the best job in education. It makes no sense to have too little technology around to have maximum effect. Educators must be more aggressive in selecting and implementing information technology just as they have successfully dragged texts and curricula into the twenty-first century. They must demand appropriate technology to do the job. Early adopters around the world have shown amazing benefits of well-chosen information technology. This article describes various problems in education and simple yet effective solutions.

Contents

1 Introduction

Ten years ago, the personal computer and the network began to make an impact in education, for those fortunate enough to have money. Schools spent a few thousand on personal computers and some on a Local Area Network (LAN) and made some use of it. Labs were built. Costs were so high that many schools still do not have computers in classrooms. Many run systems for years after they become obsolete. Most of those systems are now thoroughly obsolete for several reasons:

- the requirement to expose students to technology similar to that currently used in business which renews technology every few years (partly due to the Wintel treadmill and partly to reduce maintenance and to increase performance)
- the requirement in the curriculum to integrate technology in the classroom
- approximately every 18 months the capability of central processors doubles (Moore's Law)
- parallel evolution of several technologies (networking, disc storage, removable devices, fast memory) including software
- rapid growth of the Internet, a resource too valuable to neglect but it cannot be used effectively without more computers

Rather than attempt to implement information technology widely, education has viewed information technology as an expense to be avoided. This does no service to students or teachers and provides a poorer standard of education. It is also intellectually dishonest because the philosophy of information technology, the reason for its being, is that one seeks faster, less expensive ways of doing everything. Information technology, properly implemented, should take advantage of the fever in the world to produce ever more cost-effective IT and be used freely in education. The cost can be very small in comparison to the benefits.

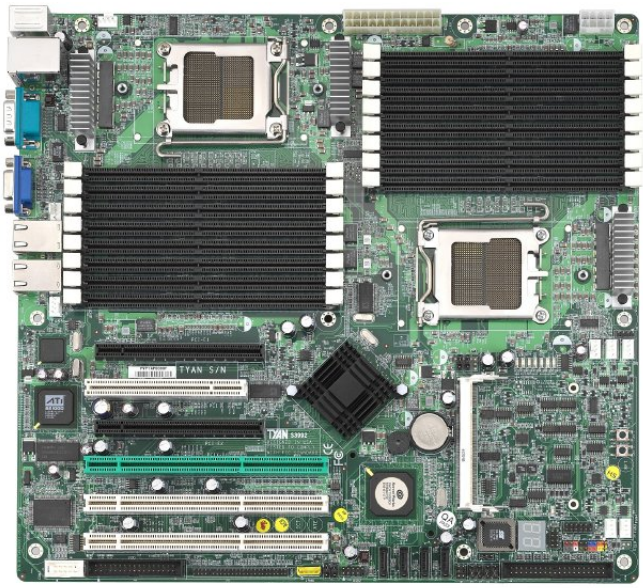
Where have things gone wrong? Much of the blame can be placed at short-sighted thinking by major corporations who provided and promoted IT in the 1990s. IBM had granted Microsoft a monopoly on the operating system with the IBM-compatible PC. IBM had carefully arranged that Intel would not have a monopoly on the CPU chips by requiring second sources. Microsoft exploited its monopoly mercilessly to exclude competition in operating systems and basic applications in the 1990s. The rapid growth of IT with rapidly falling hardware prices turned Microsoft's small licensing fee into an enormous windfall. Intel was also involved. Between the two evolved an entire generation who thought of nothing but one or more licence fees and a hard drive per PC requiring ever more powerful CPUs to run modern software. While businesses could afford the cost of monopoly, education could not. Using more IT in education did not bring in more cash flow... Microsoft was convicted of illegal trade practices and made to play more fairly but the damage has been done. The IT with the most mindshare in education was unaffordable.

2 Thinking Outside the Box

The Wintel monopoly is a box. Educators must start thinking outside the box. When we peek over the side of the box we can see other solutions to the problem of providing IT in education. Industry was faced with the identical problem in the earlier years of IT *before the PC*. Computers in those days were terribly expensive and only big business or well-funded universities could afford them. They cost millions of dollars. The solution? Terminals, small, less expensive devices to give access to the computing power of the mainframe. The current technology in a modern PC is much more powerful than the old mainframe computers. Instead of clock speeds in millions of cycles per second, megaHertz, we have CPUs that cost of the order of $100 with speeds in the thousands of megaHertz, gigaHertz. The old mainframes had megabytes of memory. We have gigabytes today. The same technology that permits a full-size PC to be powerful can be used to produce a very low cost terminal that uses only a few watts of power and is adequate to the task of displaying screens from a central powerful machine and sending information back. A full-sized PC with Microsoft software may costs many hundreds of dollars and require a lot of maintenance. A tiny terminal with no fans or storage drives can cost less than $100 and require no maintenance[2]. When educators stick their heads up over the side of the box, the problem of how to implement IT in education disappears. Where is the problem if we can provide at least twice as many seats on the system for the tiny amount we now spend on IT? Schools can easily afford a lab and several PCs in every classroom all the while saving money on hardware, software and energy.

2.1 Hardware

If we save a lot of money by using many inexpensive terminal PCs (thin clients), where do we do the computing? On a server connected to the client by a network, serving a hundred or more thin clients. Even a regular PC with added memory and storage can serve in a small school, but for most a beast with a motherboard like this is needed[3]. A few hundred watts of power can run a whole school much faster than conventional PCs which must seek hard drives to find data. This monster can store a lot of data in fast memory. It can store data on many hard drives larger than a terabyte. Fully loaded it costs only a few thousand dollars. Upgrading it every few years upgrades the whole system allowing education to maintain current IT.



The network connection from the server to the client can use gigabit/s networking. Each gigabit/s link can run 50 terminals comfortably. This motherboard can hold two quad-core CPUs giving as much computing power as 800 regular PCs idling at low utilization for a fraction of the cost (8 processors at 100% utilization compared to 800 processors at 1% utilization). A GNU/Linux terminal server also does less work per process because it uses shared memory. Only one copy of an executable need be in memory instead of one per process as one would have on a regular PC. Machines like this can do 100000 context switches per second making all processes appear to run simultaneously.

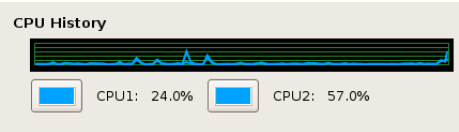


Figure 1: CPU utilization - one user with two processors - occasional spikes in activity, otherwise near zero.

2.2 Software

Now that we are thinking outside the box, we can use something other than Apple's OS/X or Microsoft's Windows. Why not? The students do not care. They want words, pictures, sounds and the monopolies do not have a monopoly on software, only mindshare of those thinking inside the box into which they have been pushed for decades.

In the early 1990s there was a family of operating systems, UNIX, that could have met the needs of education very well, but its owners sought huge license fees that were well out of reach for most. A Finnish student, Linus Torvalds, in 1991 was toying with the idea of building a UNIX operating system that would be free for all, with no license fee. Within a year he had a handful of people sharing efforts over the Internet to build Linux. Within a few years it was usable. By the late 1990s it could well have served education[15]. Properly called the GNU system with the Linux kernel or GNU/Linux, this operating system was installed on millions of PCs and was widely used in business on the server. By 2000, I was using it on PCs at Whale Cove, NU. I had five PCs running Windows '95 (Lose '95). Every hour one or another of them would freeze and they were so old and slow it took 5 minutes to reboot. This was very distracting for students. I knew software should be better than that. I downloaded an installation CD for Caldera GNU/Linux (10 days of nights and weekends) and installed it. There was not one freeze the rest of the year.

In those days it was easy to obtain Netscape web browser and Star Office, distributed by SUN Microsystems for GNU/Linux at no cost. That was about all we needed to bring an abundance of resources to the classroom. Eight years later, there has been a continuing explosion of free open-source software around the world. GNU/Linux is on one hundred million PCs and one can buy PCs with GNU/Linux installed at the factory from many major Original Equipment Manufacturers (OEM). Instead of a single CD of software for GNU/Linux it takes 23 to hold just the Debian GNU/Linux distribution. One website, Sourceforge.org,

hosts more than one hundred thousand free software projects. Free software is a cooperative project of the world. It is free for anyone to use, including educators and students. Because the software is designed for its performance and not its ability to solidify the Wintel monopoly, the software works for education and not against education. There is no malware to speak of, no DRM, no Vistaesque lethargy. It just gets the job done.

2.3 Money

Love of money is the root of all evil[1]. That is the case here. The monopolies went so far milking the system that non-profit organizations were squeezed. Now that the cost/performance ratio of hardware is so low, and software is free what can we do?

- spend much less on power consumption while doing more IT (is there leverage in NU where power depends on diesel fuel?)
- spend much less on paper/toner/printers because we can view on-screen and share over the network
- provide local search because the normal terminal server can do that and provide authentication, file sharing, web service and database all at once (imagine having the computer find your files in an instant instead of pouring through folders/directories/drives)
- distribute free copies of software to staff and students for use at home

Let us do a calculation. Suppose we want 100 PCs in a school. Using GNU/Linux and thin clients, we can build a station for about $250 (client PC, LCD monitor, keyboard and mouse). A server to run the whole school costs about $3000 (dual AMD Opteron quad-core with 8GB memory and 6 500 GB hard drives). If we assume the existing network will bring 100 mbits/s to each classroom we can use a $50 network switch to connect the clients to a single cable in each room. The lab should have a gigabit/s switch costing perhaps $100. The total cost for 100 new, high-performance PCs is only about $30000 or $300 per seat. That is what some pay for a single lab of the usual Wintel PCs and their software which we do not need. This changes what is possible. This changes what we can do with IT in education.

2.4 Performance

In 2006, I had the opportunity to construct the entire IT system of a new school of 500 students in Easterville, MB. The entire IT capital budget not including the network was $100000, a pittance if we used Wintel. Instead we used thin clients, in those days, costing $139 and freight. We bought 96 of those and built 13 custom PCs with 6 video cards permitting six simultaneous users[4]. Those boxes cost about $100 per seat. The total was 153 seats along with six colour printers, 8 black and white printers, 5 scanners and 6 digital cameras. We built six custom servers with AMD64 X2 CPUs. One had 2gB RAM for authentication and file serving. The others were general purpose terminal servers with 4gB RAM on which users ran their applications. Typically the servers had 25% CPU usage and the network was never maxed out. Storage was on RAID 1 arrays of four 500 gB hard drives in the file server. The terminal servers had four smaller drives for booting and loading software. It was very simple to manage. An administrator could log in anywhere and control all the servers by typing simple commands on a console. A single command could update all software or just one server for testing. 700 computer accounts were generated automatically by scripts. It took just minutes a day to administer, mostly watching it hum. In two years of operation the only serious problem was one hard drive failure which prevented booting. Removing the hard drive and booting from another drive with mirrored image solved the problem.

Others have had similar experiences. North Battleford went from 300 PCs with Wintel to 1440 thin clients using Solaris UNIX with no need to add IT staff. That is typical. Capital costs are less than half and operating costs are much less for maintenance[5].

2.5 Limitations

Of course, every system has its limitations, just as Wintel does not fit in the budget. Thin client/server systems rely heavily on the server. For full-screen video, the bandwidth of the network or the throughput of the server will likely be a limiting factor. Typically, this is overcome by keeping one thick client in each room with a projector or large screen monitor instead of showing video on each screen. Part screen video such as

often used in flash presentations on web pages is no problem. The probability that sufficient users attempt full-screen video simultaneously to clog the system is very small except, perhaps, at a film festival or "Film Friday". Being aware of the limitation and scheduling around it may be sufficient. This really is not much different from having to ban streaming video on some of our present system because the Internet connection cannot handle it.

We can also have problems moving files created on GNU/Linux being used on Wintel systems. This is because Wintel uses proprietary file format which are frequently changed to pressure users to upgrade to the latest versions of software (and new licensing fees). This document was produced on GNU/Linux using LyX. I exported it as PDF (Portable Document Format) which is widely used to distribute curricula and guides in education so it can be easily used on any system. For word-processing we use Open Document Format (ODF), an open standard which Microsoft does not support yet but we can export as Word '97 which works fairly well or PDF.

2.6 Other Benefits

So far we have mostly emphasized that we can have much more IT in education using GNU/Linux with terminal servers. This is a very important limiting factor which makes proper use of IT in education possible. Some schools even have one PC per student and they can afford it because a fan-less thin client has no moving parts, does not collect dust, and lasts ten years or more. If all a school has to do to stay current is to upgrade the server frequently, costs of software installation and management become trivial.

The real benefit of education once there is enough IT that every student can use IT in every classroom frequently is that there are many more ways IT can be used:

- a school can afford many more free applications than proprietary ones[6].
- a school can legally give copies to staff and students to use at home[7]
- a school can run network services of many kinds (chat, printing, e-mail, web, dictionary, translation, search) locally or on the web at no extra cost
- a school can run social/group web applications and databases locally, avoiding the Internet bottleneck. e.g. Moodle[8] course management, Gallery2[11] image database, Wikimedia[9], just like Wikipedia.org[10], etc.
- search is vital for education. Just as we can search the web, there are free software applications for searching the local file systems. Terminal servers make this trivial since there are fewer file systems to search (all files can be kept on one server). e.g. SWISH-e[12]

With GNU/Linux terminal servers the problem of how to manage to do anything is replaced with a pleasurable problem: Which of several ways available can best be used to teach this subject matter? In fact, once staff and students are comfortable with the system, they will wonder how they ever got along without it. It feeds the fire of productivity since everyone's product can be put on display to the whole organization. Everyone tries to out-do the other. The quality of work improves and the quantity explodes.

3 Conclusion

Because a small trial setup can be implemented for very little cost, every school can afford to try GNU/Linux terminal servers, and to build local expertise. The only additional hardware needed to convert a regular PC with 512 MB RAM into a GNU/Linux terminal server is a second network interface if it is to connect to an external network. For an isolated system there is no additional cost. A software distribution such as Edubuntu has installation options to set up the server and it can be operational in 20 minutes. EdUbuntu[13] will even send you an installation CD at no charge[14]. Using this technology plus knowledge of IT already in-house empowers any school to implement this solution.

The only remaining obstacle is money. If anyone tells you there is no money, demand some of the money being paid for proprietary software licences (the amount is astounding) or diesel fuel to power full power PCs (around $100 per PC per year), some of the cost of paper and toner which will not be needed if more information is passed along the network and viewed on screens instead of on paper or the cost of replacing moving parts (fans/discs/power supplies) that fail. There is money being spent on IT sufficient to replace

the old system with a new one every few years. Phase it in if you have to. It is worth the effort. All it takes is a coordinated effort to get various parties to cooperate: government, divisions, schools.

Every school should have an IT committee tasked to provide feedback from users, and to plan for integration of IT in the curriculum. Every teacher should know what is possible to do with IT in education and to choose what works best for the students and subject matter. With proper use of IT we can do more with less and faster.

References

[1] Bible, King James Version, I Timothy 6:10 "For the love of money is the root of all evil: which while some coveted after, they have erred from the faith, and pierced themselves through with many sorrows."

[2] ebox-2300, a fan-less thin client. DMP Electronics, Taiwan, $77 in hundred quantities.

[3] TYAN S3992 Dual Opteron Socket-F with 16 DDR2 memory sockets and 4 SATA drive sockets.

[4] Groovix.com - multiseat X free software to permit multiple X servers and multiple sessions on one PC.

[5] http://se.sun.com/edu/pdf/sunray-k12-success.pdf Solaris thin clients installed in four school divisions in 2000.

[6] http://packages.debian.org has more than 20000 software packages. A little more than 2000 make a very good system, but a school can install twice that for very little expense except the time it takes to download them.

[7] http://www.gnu.org The GNU Public Licence covers most free software and permits the recipient of the software to run it, examine it, change it and to re-distribute it under the same terms as the software was received.

[8] http://moodle.org Moodle is a course management system which can be used for distant education or to offer more courses in Career and Technology Studies (CTS) or other courses in a multi-grade/multi-level/individualized programme.

[9] http://wikimedia.org Wikimedia is a searchable and editable web application which is used in Wikipedia and many other purposes. A school can have as many wikis as they want on their server. They can have local copies of many found on the web or make their own for any purpose.

[10] http://en.wikipedia.org is a huge on-line encyclopaedia created by visitors to the site. It is very dynamic and sometimes controversial but its size and currency make it important in education. Schools can keep a local copy to permit filtering/editing for appropriateness. Teachers can add/change content to suit their educational objectives. Students can contribute images and text, too.

[11] http://gallery.menalto.com Gallery2 is a web application that holds annotations of images in a database for instant retrieval of images by searching. Each teacher/student/class/school/division can have its own image gallery made available on the network.

[12] http://swish-e.org SWISH-Enhanced is a fast, powerful, flexible, free, and easy to use system for indexing collections of web pages or other text files. For instance, a school can have an index of every shared file on the whole system. Searching is instant for keywords, seconds for phrases. For years, I have kept a local copy of text files from Gutenberg.org on my server and using SWISH-e I can find any of 11000 books instantly. This is like an electronic library for a school.

[13] http://edubuntu.org Has an option to make a default installation of a terminal server. It takes only 20 minutes on a newer PC.

[14] http://shipit.edubuntu.org will even mail you the installation CD. Delivery is ten weeks so you may prefer to download a CD image.

[15] http://www.groklaw.net/staticpages/index.php?page=20051013231901859 "The Daemon, the GNU & the Penguin" by Dr. Peter Salus